§31. Intermittency and Transfer Phenomena in NS and MHD Turbulence

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It has been widely considered that when the Reynolds and magnetic Reynolds numbers are very large, spectrum of the total (kinetic plus magnetic) energy obeys Iroshnikov-Kraichnan(IK) scaling, $E^T(k) = C_{IK}(\epsilon v_A)^{1/2}k^{-3/2}$, where C_{IK} is a nondimensional constant, ϵ the average rate of the total energy dissipation, and $v_A \propto \sqrt{\langle \boldsymbol{b}^2 \rangle}$ the Alfvén velocity. However, recent studies have claimed that the Kolmogorov(K) scaling $E^T = C_K\epsilon^{2/3}k^{-5/3}$ holds. We have numerically studied this scaling of the spectrum by direct numerical simulation of turbulence. Also high order statistics of the fields and their scaling exponents have been examined.

The equation for the Elsässer variable $\boldsymbol{z}^\pm = \boldsymbol{u} \pm \boldsymbol{b}$ was integrated. The random force was applied at low wavenumber bands for the momentum equation alone, and statistical average was taken over time. The number of grid points was 128^3 and 256^3. The magnetic Prandtl number is unity and Taylor microscale Reynolds numbers were 92 and 160.

Figures 1 and 2 show the energy spectra compensated by multiplying $k^{3/2}$ or $k^{5/3}$ and by normalizing in terms of IK or Kolmogorov scaling valriables, respectively. It is difficult to definitely determine which scaling is preferred in the inertial range because of insufficient width of the range, but the IK scaling looks to work better in the dissipation range.

In MHD turbulence, a 4/3 law, counterpart to the 4/5 law in NS turbulence, is known to hold in the inertial range;

$$\left\langle \delta z_{\parallel}^{\mp} \delta z_i^{\pm} \delta z_i^{\pm} \right\rangle = -\frac{4}{3}\epsilon^{\pm} r. \qquad (1)$$

This equation implies that $\delta\boldsymbol{z}^\pm$ would obey the Kolmogorov scaling if the intermittency is ignored. It was found that the third order moment of $\delta\boldsymbol{z}^\pm$ gradually approached the 4/3 law when the Reynolds number was increased (figure not shown). The structure functions of $\delta\boldsymbol{z}^\pm$ at low to moderate order were also computed, and their scaling exponents in the inertial range are shown in Fig. 3. Values of the scaling exponents are closer to the Kolmogorov scaling than to those by the IK scaling. However, it should be noted that the magnetic energy is about a quarter of the kinetic energy, which means that the characteristic time related to the Alfvén velocity is premature to dominate the energy transfer towards high wavenumbers. This might be a reason for nearly Kolmogorov scaling. Certainly further examination would be required.

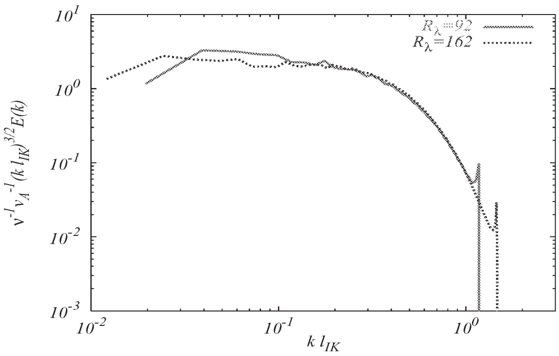

FIG. 1: Iroshnikov-Kraichnan(IK) scaling of the energy spectrum $(\nu v_A)^{-1}(kl_{IK})^{3/2}E^T(k)$

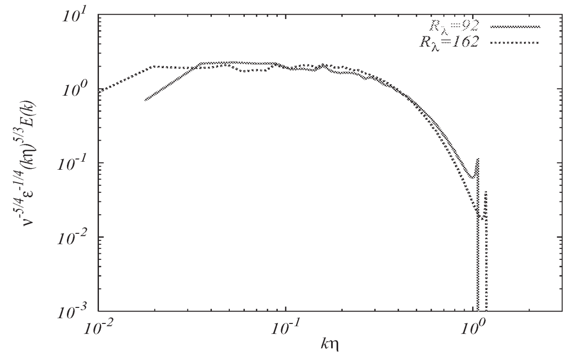

FIG. 2: The Kolmogorov scaling of the energy spectrum $\nu^{-5/4}\epsilon^{-1/4}(k\eta)^{5/3}E^T(k)$

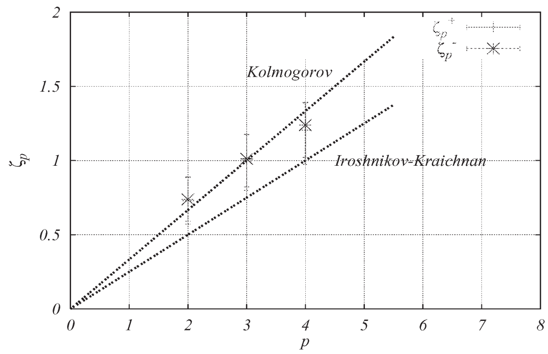

FIG. 3: Scaling exponents $\zeta_p^\pm$ of the structure functions of the Elsässer variable increment.

References

1). Gotoh T. and Mori K.: *Energy spectrum and transfer flux in Hydrodynamic and MHD turbulence* Proceedings of Workshop on Interdisciplinary Aspects of turbulence, Max Planck Institute for Astrophysics, (2005).